技術資料No. 5

電弧爐煉鋼文獻集

（第一輯）

中華民國鑄造學會 編印

中華民國六十年十月

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C O N T E N T S

ELECTRIC FURMACE OPERATION AND RAW MATERIAL PREPARATION

by

Dr. Hiroshi Noda

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I PREFACE

1. Criterion of "Mini Mill"

Annual production capacity $\leq$400,000 t
Major products .... merchant bars and structurals
Melting furnace ... arc furnace

2. Why arc furnace

1) less capital cost, higher return on investment
2) smaller incremental capacity expansion steps.
3) less land required
4) pollution control - much simpler less costly
5) electricity is probably the only energy projected to remain stable or even decline in cost over the long term.
6) higher potentiality to reduce costs by technological improvements.
7) more metallurgical flexibility more production flexibility
8) best source of hot metal for increasing continuous casting etc.
Accelerator (UHP furnace
(prereduced material
(full automatic operation

II ARC FURNACE FOR MINI MILL

1. Estimated schedule

Assumption Single slag, carbon steel, continuous casting, three shifts.

	Case I	Case II	Case III
Annual production (1,000t)	100	200	400
Molten steel (1,000t)	110	220	440
Molten steel (t/U)	15.3	30.6	61
Schedule A Two x UHP furnace			
furnace size (t)	20	40	70
nominal capacity of furnace transformer (MVA)	15	27.5	40
melt down input (MW)	10	19	28
* average input (MW)	7	13	21
* tap to tap (h)	2.3	2.3	2.3
* productivity per furnace (t/h)	7~9	14~17	27~31
melting power demand (MW)	20	37	55

	Case I	Case II	Case III
Schedule B two x RP furnace			
furnace size (t)	25	50	100
nominal capacity of furnace transformer (MVA)	10	18	30
melt down input (MW)	8	15	24
* average input (MW)	6	11	20
* tap to tap (h)	3.1	3.2	3.6
* productivity per furnace (t/h)	7~8	14~16	28~31
melting power demand (MW)	15	30	45

* subject to change up to 25~30%

~ with improved organization and experienced operation.

	improved operation	prereduced material
average input	↗	↗
power consumption	↘	↗
tap to tap	↘	↘
productivity	↗	↗

2. Review of UHP principles

Ultra high power resulting in Ultra high productivity represents a package of a number of criterion

a) specific power level melt down power kw per ton of furnace capacity 400~500 for mini mill size.

b) ratio of average power to maximum melt down power > 0.7

c) time utilization
total power on time/tap to tap ≥ 0.7

d) matching of arc power and arc length to heat transfer conditions, shortest arc, power factor.

e) electrical power balance of the three arcs
triangular spacing
water cooled cables

Advantages

increased productivity
better thermal efficiency
less capital investment for equivalent capacity.
less voltage flicker

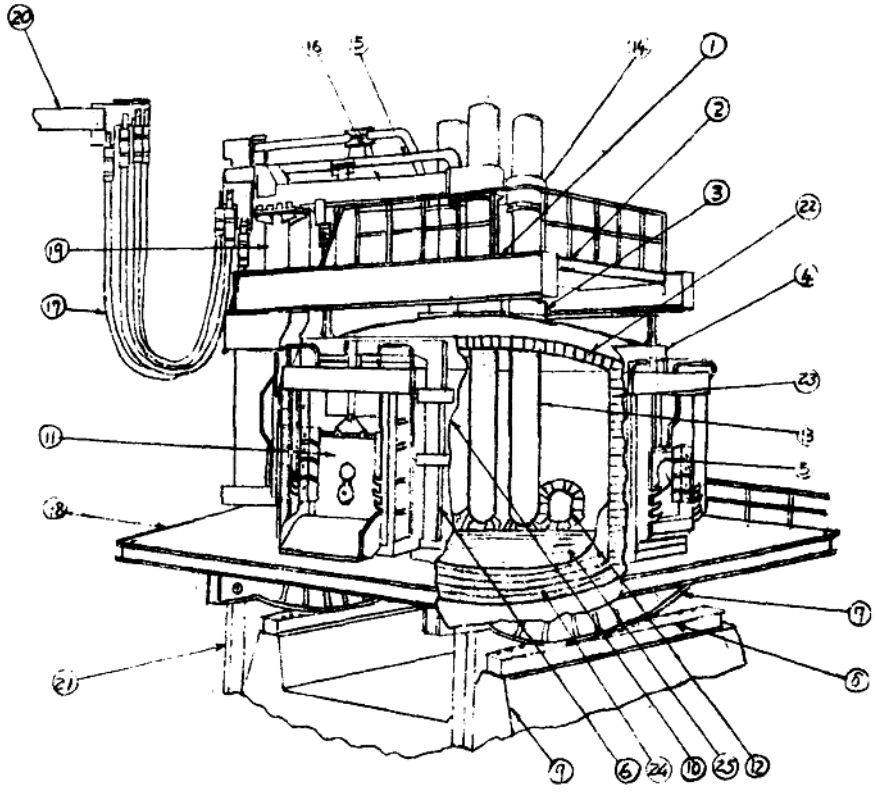
3. Typical construction of arc furnace (Fig. 1)

4. Standard specifications (JIFMA)

See Appendix 2.

FIG. 1

CONSTRUCTION OF ARC FURNACE



1. Roof Ring Suspending Outrigger Beam
2. Roof walkway
3. Electrode Cooling Gland
4. Furnace Roof
5. Working Door
6. Door Operating Mechanism
7. Furnace Rocker
8. Furnace Pedestal Track
9. Foundation
10. Furnace Shell
11. Slagging Door
12. Tapping Hole
13. Electrode
14. Electrode clamp
15. Bus Tube
16. Electrode Arm
17. Water Cooled Cable
18. Tilting Platform
19. Electrode Column
20. Secondary Bus Bar
21. Tilting Mechanism
22. Roof Refractories
23. Side Wall Refractories
24. Bottom Lining
25. Molten Metal

5. Standard dimensions (JIFMA)

Furnace size (ton)	Shell dia. (mm)	Electrode dia (mm)	Transformer capacity UHP (MVA)	RP (MVA)
10	3,350	300	10	5
15	3,650	350	12.5	6
20	3,950	350	15	8
25	4,300	400	17.5	10
30	4,600	400	22	12.5
40	4,900	450	27.5	15
50	5,200	950	30	17.5
60	5,500	500	35	20
70	5,800	500	40	22.5
'	'	'	'	'
'	'	'	'	'
'	'	'	'	'
'	'	'	'	'
400	9,800	600	200	-

6. Example of arc furnace layout (Fig. 2)

7. Installation cost of arc furnace

equipment	percentage (example)
raw material preparation	11
furnace	52
dust collector	2
(molding)	(24)
substation	10
other auxiliaries	1
Total	100

Cost examples.

8. Personnel

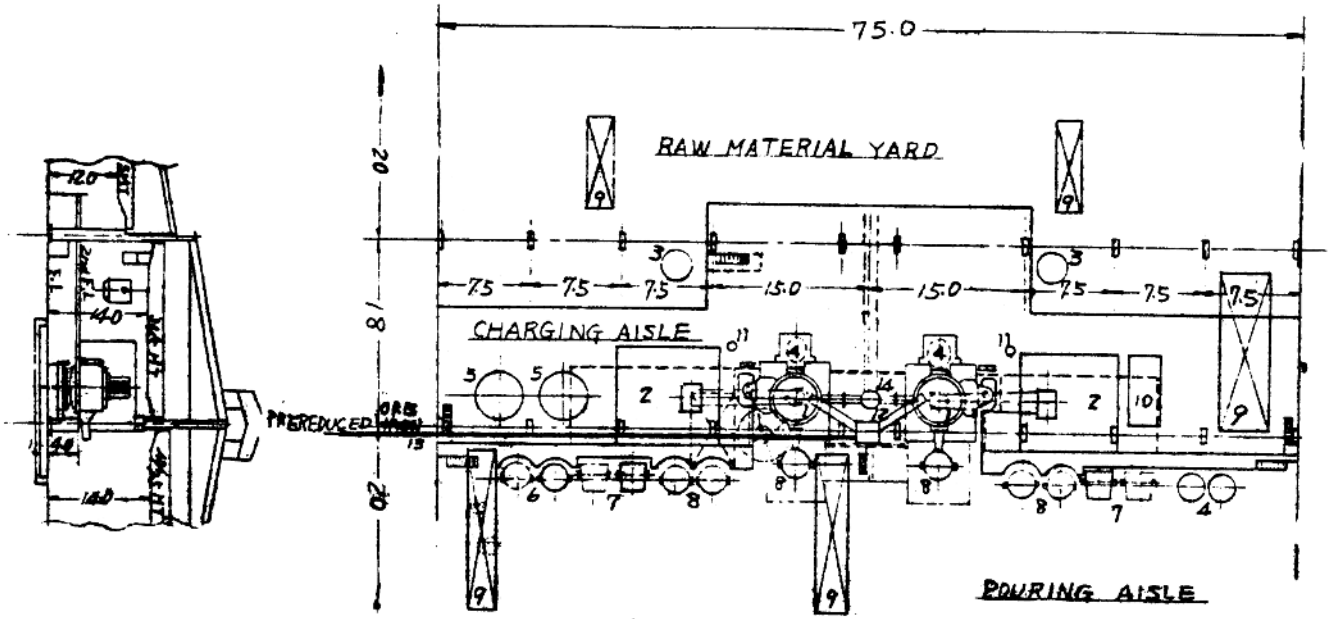
Estimated personnel required for operation and maintenance of two minimill arc furnaces

	per shift
Chief Melter	1
arc furnace	8
ladle man	3
crane man	2
raw material preparation	6
additional material preparation	2
relining of furnace and ladle	4
chemical analysis	2
maintenance electrical	1
mechanical	1
crane	1

9. Characteristics of arc furnace

heavy current arc
power characteristics.

Fig. 2 ONE EXAMPLE OF TWO-20M.T. ARC FURNACE LAYOUT



P.NO	DESCRIPTION	P.NO	DESCRIPTION
1	20M.T. Arc Furnace	8	Ladle
2	Transformer Room	9	Crane
3	Charging Bucket	10	Electrode
4	Slag Pan	11	Immersion Pryometer
5	Spare Roof	12	Hoppers
6	Ladle Relining	13	Conveyer
7	Ladle Preheater	14	PUME Extraction System

10. Operations

Carbon steel - basic single slag.

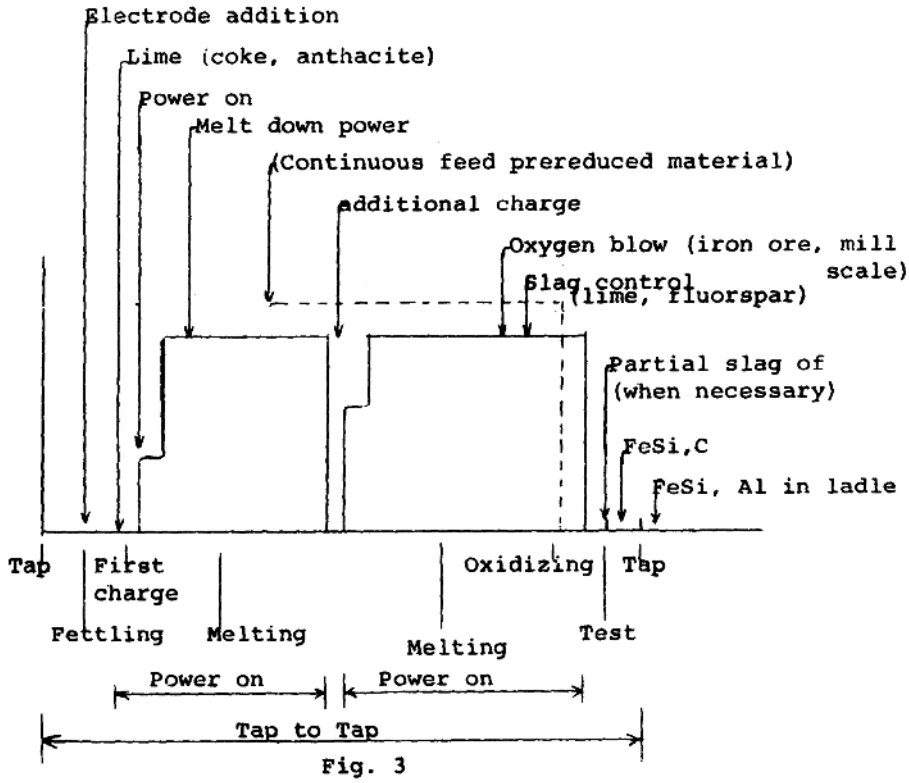


Fig. 3

11. Material and energy consumption per ton of molten steel.

Scrap		1,035～1,100 kg	220 kg
prereduced material		-	900 kg
ferro-manganese		6 kg	6 kg
ferro-silicon		3 kg	5 kg
aluminum		0.5 kg	0.5 kg
lime		50 kg	80 kg
coke		2 kg	2 kg
Fluorspar		10 kg	5～10 kg
oxygen		5～8M^3	-
magnesia clinker (ordolomite)		20 kg	20 kg
roof refractories		3 kg	3 kg
wall refractories		4 kg	4 kg
electrode		5.00 ～	5.5 kg
electricity	Case I	550 ～ 600 Kwh	
	Case II	520 ～ 570 Kwh	
	Case III	500 ～ 550 Kwh	

12. Estimated production cost

Metallics - (M)

plant scrap (return scrap)
purchased scrap
purchased prereduced material
additions

Cost above - (C)

electricity
electrode
refractories
fluxes
fuels, utilities and supplies
repairs and maintenance
supervision and labor
general overhead

Total cost of molten steel (M + C)
Fixed charges (to be calculated on the final cost of product)

Ex. O US Mini Mill (1970)

100,000 NT
scrap base $46.15/NT = $51
40% prereduced material base (at $41/NT) $50.23/NT
= $55.5

O Japan (1971)

300,000 t plant

cost above = ¥8,000/t

III. RAW MATERIAL PREPARATION

1. Raw materials

plant scrap (return scrap)
purchased scrap, purchased pig iron
purchased prereduced material
produced prereduced material
purchased ferro alloy

2. Preparation of scrap

scrap yard
scrap press
scrap preheating
shredded or fragmentized scrap

Hammer Mills
Williams
Lindemann
Puremelt
Eidal
Inch etc.

3. Prereduced materials

Process SLRN, Midrex, HyL
HIB, Purofer, Krupp-Renn
Armco etc.

Projected plant (1,000 t per year)

1971	SLRN	Falconbridge	300
	Midrex	Georgetown	400
	Midrex	Hamburg	400
	HIB	Puerto Ordaz	1000

1972	Armco	Houston	300
	Midrex	New Orleans	400
	Midrex	Japan	400
1973	SLRN	Hamersley	1,400

Distribution of world market for prereduced iron ores: 1975 - 1980

by J.R. Miller (U.S.A.)

(In percent and millions of metric tons)

	1975		1980	
Region	%	Tons	%	Tons
North America	20	2.2	24	14.8
South America	22	2.4	9	5.6
Western Europe	4	.5	14	8.7
Eastern Europe	-	-	10	6.2
Asia	34	3.7	29	18.0
Africa	7	.8	6	3.7
Oceania	13	1.4	8	5.0
Total	100	11.0	100	62.0

4. Technical aspects for using prereduced material

- continuous feeding process
- continuous feeding equipments
- productivity and yield
- melting power and feed rate
- power consumption
- electrode consumption
- refractory maintenance
- reoxidation, boiling, slag volume
- load factor, disturbance

IV COMPLEMENTS

1) Dynamic characteristics of arc furnace
2) Flicker and power availability
3) Refractory wear index
4) Technological development of related equipment

material handling
slag granulation
fume control
computer control
mechanized operation
fuel addition
rapid refining

5) Future prospect of arc furnace

APPENDIX

1. Mini steel plants in the United States

2. Standard specifications for arc furnace

3. Flicker suppression methods.

APPENDIX 1

(From 33/the Magazine of Metals Producing)

Mini steel plants[1] in the United States

(as of January 1971)

	COMPANY AND LOCATION	RAW STEEL CAPACITY NT PER YEAR	MAJOR PRODUCTS	STEELMAKING FURNACE CAPACITY[2]	CONTINUOUS CASTING
1	ALLISON STEEL, GETZ BROS. SUBS. Tempe, Arizona	150,000	Merchant bars	3-20	No
2	AMERICAN COMPRESSED STEEL Cincinnati, Ohio	12,000	Merchant bars	1-6	No
3	AMERON STEEL PRODUCING DIV. Etiwanda, California	160,000	Merchant bars & coils	2-10 1-15	Yes
4	ARMCO STEEL CORP. Sand Springs Works Sand Springs, Oklahoma	300,000	Merchant bars, special structurals	2-70	Yes
5	BORDER STEEL MILLS El Paso, Texas	140,000	Merchant bars	2-25	No.
6	BORG-WARNER, CALUMET STEEL DIV. Chicago Heights, Illinois	180,000	Merchant, special bars, light structurals	2-30	Yes
7	CASCADE STEEL ROLLING MILLS McMinnville, Oregon	130,000	Merchant bars	2-20	Yes
8	CF&I STEEL CORP. ROEBLING PLANT, Burlington County, New Jersey	200,000	Wire	3-43	No
9	CONNORS STEEL DIV., H.K. PORTER CO Birmingham, Alabama	200,000	Merchant bars & structurals	1-15 2-20	Yes
10	Huntington, West Virginia	150,000	Merchant bars & structurals	2-30	No
	FLORIDA STEEL				
11	Croft, North Carolina	100,000	Merchant bars	1-25; 1-20	No
12	Indiantown, Florida	90,000	Merchant bars	1-30	Yes
13	Tampa, Florida	200,000	Merchant bars & structurals	1-25; 2-20	Yes
14	GEORGETOWN STEEL Georgetown, South Carolina	400,000	Merchant bars	2-65[3]	Yes
15	HAWAIIAN WESTERN STEEL Ewa, Hawaii	50,000	Merchant bars	1-15	No
	INTERCOASTAL STEEL Chesapeake, Virginia	80,000	Merchant bars	2-20	No
17	JONES & MC KNIGHT CORP Kankakee, Illinois	100,000	Merchant bars	2-15	No
18	JUDSON STEEL CORP. Emeryville, California	75,000	Merchant bars	1-45	No
19	KENTUCKY ELECTRIC STEEL Ashland, Kentucky	120,000	Merchant bars & structurals	2-15	Yes
20	KNOXVILLE IRON CO. Knoxville, Tennessee	100,000	Merchant bars	2-10; 1-25	Yes
21	LEMONT MANUFACTURING CO. SUBSIDIARY CECO CORP. Lemont, Illinois	240,000	Merchant bars & structurals	3-30	No
22	MILTON MANUFACTURING CO. DIVISION CECO CORP. Milton, Pennsylvania	170,000	Merchant bars & structurals	3-20	No
23	MISSISSIPPI STEEL DIV. OF MAGNA CORP. Jackson, Mississippi	80,000	Merchant bars	2-10	No
24	NEW JERSEY STEEL CORP. Sayreville, New Jersey	120,000	Merchant bars	1-50	Yes

25	NORTH STAR STEEL St. Paul, Minnesota	300,000	Merchant and special bars	2-60	Yes
26	NORTHWEST STEEL ROLLING MILLS Seattle, Washington	100,000	Merchant bars	1-30	No
27	NUCLEAR CORP. OF AMERICA EASTERN CAROLINA STEEL DIV. Darlington, South Carolina	120,000	Merchant bars	2-20	Yes
28	OREGON STEEL MILLS Portland, Oregon	350,000	Merchant bars & plate	3-20 1-80[3]	Yes[4]
29	OWEN ELECTRIC STEEL CO. Cayce, South Carolina	100,000	Merchant bars	1-15 1-10	No
30	PACIFIC STATES STEEL CORP Union City, California	400,000	Bars & structurals	4-150 (OH)	No
31	POLLAK STEEL Marion, Ohio	100,000	Merchant bars	1-30	Yes
32	ROANOKE ELECTRIC STEEL Roanoke, Virginia	170,000	Merchant bars	1-12; 2-25	Yes
33	ROBLIN STEEL Dunkirk, New York	100,000	Special bars & wire rod	2-25	Yes
34	Tonawanda, New York	300,000	Special bars and wire rod	2-70	Yes
34A	ROSS STEEL WORKS Amite, Louisiana	100,000	Merchant bars	1-30; 1-10	No
35	SOULE STEEL Long Beach, California	100,000	Merchant bars	1-15	Yes
36	SOUTHWEST STEEL ROLLING MILLS SUB. AUTOMATION IND. Los Angeles, California	100,000	Merchant bars	1-18; 1-15	No
37	SOUTHERN ELECTRIC STEEL DIVISION OF GECO CORP. Birmingham, Alabama	85,000	Merchant bars	2-14	No
38	STRUCTURAL METALS Sequin, Texas	90,000	Merchant bars	2-25	No
	TENNESSEE FORGING STEELS				
39	Harriman, Tennessee	120,000	Merchant bars	2-25	Yes
40	Newport, Arkansas	90,000	Merchant bars	1-25	Yes
41	TEXAS STEEL Ft. Worth, Texas	150,000	Merchant bars	2-25	No
42	WASHBURN, WIRE CO. Phillipsdale, Rhode Island	120,000	Hot rolled rod & wire	2-45	No
43	WITTIMAN STEEL Fontana, California	40,000	Merchant bars	1-25	No
	TOTAL TONNAGE:	6,582,000			

The major criteria used in designating a steel plant as "mini" is (a) that raw steelmaking capacity be no more than 400,000 net tons per year, (b) products made shall not be specialty steels, flat rolled, or forgings exclusively.

[1] Electric furnaces unless indicated otherwise by OH for open hearths.

[2] Metallized pellets used or planned.

[3] Oregon Steel's casting arrangement is described as "pressure casting."

APPENDIX 2

STANDARD SPECIFICATIONS (JIFMA)

I. GENERAL

- scope of supply
- FOB
- JIS
- test
- guarantee
- ambient conditions
- packing
- drawings
- customers supply
  - power supply
  - cooling water
  - foundation
  - assembly, installation
  - wiring, piping
  - charging buckets or chute
  - refractories
  - electrode
  - roof brick template
  - lubricant
  - painting for repair
  - spare parts
  - technical service
- others

II. DETAILED SPECIFICATIONS

1. Outline of the equipment

1.1 Purpose of the furnace

1.2 Outline of the furnace

(1) Type of the furnace
(2) Molten metal capacity
(3) Diameter of the furnace shell
(4) Capacity of the furnace transformer
(5) Electrodes
(6) Method of charging
(7) Type of the electrode regulator

1.3 Production capacity at standard operating conditions

1.4 Outstanding features of this equipment.

2. Mechanical equipment

2.1 Furnace shell
2.2 Working and slagging doorway
2.3 Tilting platform
2.4 Rockers and pedestal
2.5 Roof rings
2.6 Column eye bracket and or gantry support
2.7 Roof platform
2.8 Electrode columns
2.9 Electrode arms with conductors and clamps
2.10 Electrode cooling glands
2.11 Electrode gears
2.12 Tilting mechanism
2.13 Roof lifting and swinging mechanism
2.14 Auxiliaries (Name plates, Hand tools etc.)

3. Secondary cables and bus bars

4. Electrical equipment

   4.1 Furnace transformer
   4.2 Automatic electrode regulator
   4.3 Switchgears
   4.4 Furnace control panels
   4.5 Auxiliaries (auxiliary motors, controls, etc.)

III. RECOMMENDATIONS TO THE AUXILIARY EQUIPMENT

1. Charging buckets or charging chute equipment
2. Ladles
3. Slag pans
4. Operational tools
5. Cranes
6. Roof refractory template

IV. OPTIONAL PROPOSAL

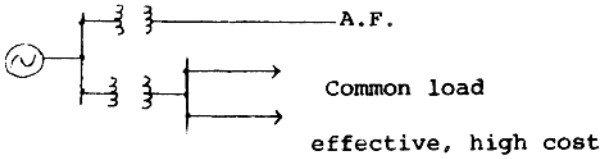
1 Dust collecting equipment
2. Equipment for flicker suppression and or power factor correction
3. Induction stirrer
4. Vacuum degassing equipment
5. Refractories
6. Electrodes
7. Instruments (pyrometer, etc.)
8. Computer control or other automatic control
9. Oxygen lancing equipment
10. Refractory guns
11. Air compressors
12. Manipulator
13. Storage batteries
14. Spare parts for one years operation

APPENDIX 3

Flicker suppression methods

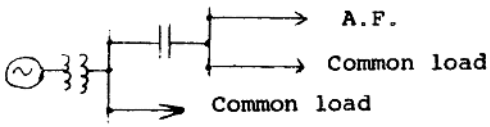
A. On system

1) system change, voltage grade change



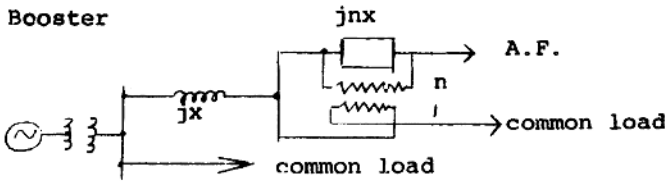
effective, high cost

2) series condenser (increase of short circuit capacity)



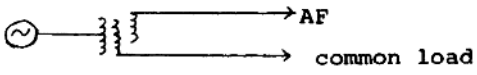
flicker reduction 50%
transient oscillating current location difficulty

3) Booster



short circuit capacity reduce

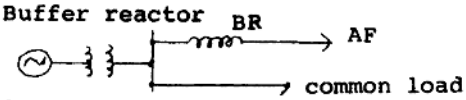
4) Three winding transformer



compensation subject to change system reactance

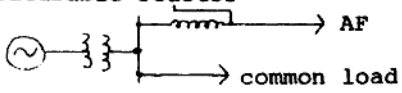
B. On arc furnace load

4) Buffer reactor



least cost
30% BR 60% reduction
input reduction, poor efficiency.

5) Saturable reactor



effective
cost > 4)

6) parallel saturable reactor